(12) UK Patent Application (19) GB (11) 2 294 604 (13) A

(43) Date of A Publication 01.05.1996

(21) Application No 9520969.8

(22) Date of Filing 13.10.1995

(30) Priority Data
(31) 9421493 (32) 24.10.1994 (33) GB

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(51) INT CL^6
G01N 22/00 25/00 , H04N 5/30

(52) UK CL (Edition O)
H4F FAAX FD18K FD2A FD27T1
U1S S2154 S2157 S2187

(56) Documents Cited
GB 2235604 A GB 2007358 A US 4965451 A
SPIE Volume 520 Thermosense VII,1984,pages 197 to 206

(58) Field of Search
UK CL (Edition O) G1A AHC AMBX , H4F FAAA FAAX FCCX FCK FDX
INT CL^6 G01N 22/00 25/00 25/72 , H04N 5/30 5/31 5/32 5/33
Online:WPI,INSPEC,DIALINDEX(ALLSCIENCE)

(54) Thermal imaging using electro-magnetic induction

(57) An imaging method comprises directing electromagnetic waves at a resistive surface 2 so as to induce currents within the surface and cause heating thereof The resulting thermal image is observed by means of a thermal imager 3. Objects passing across the plane of these waves cause distortions in the thermal image from which the presence of an object 8 within an item of luggage 7 may be detected. A further embodiment (fig 3) invokes direct excitation of an object e.g. the ground (9) to detect the presence of objects (8) beneath its surface.

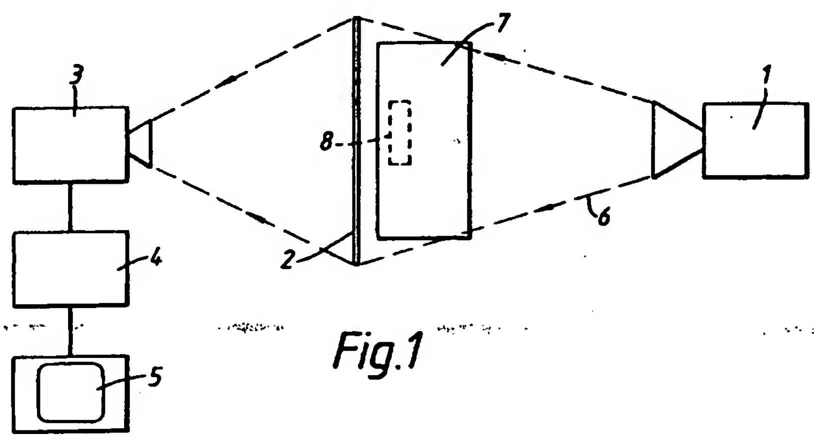

Fig.1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

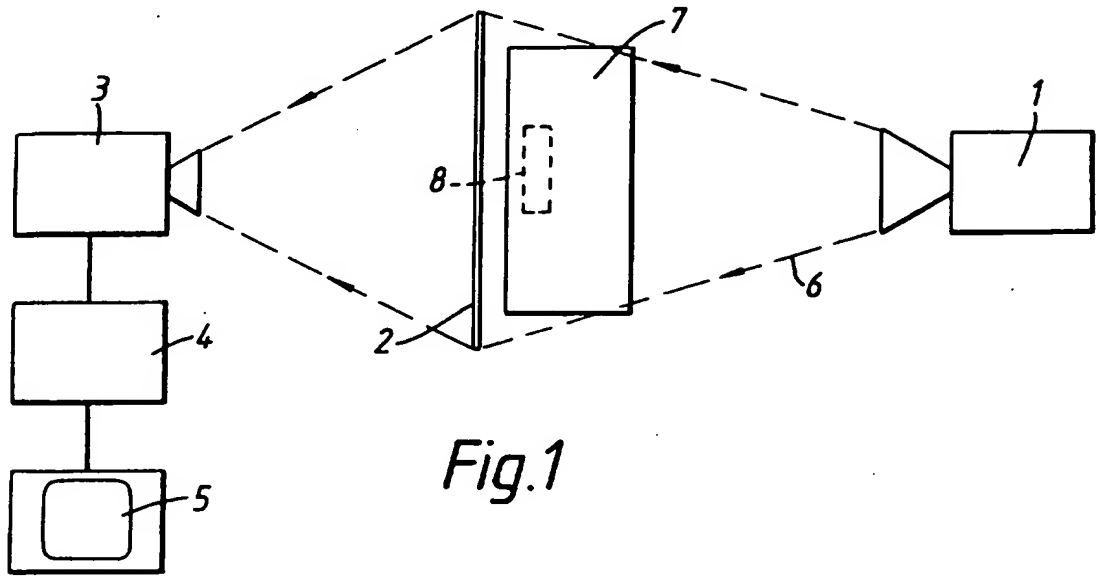

Fig.1

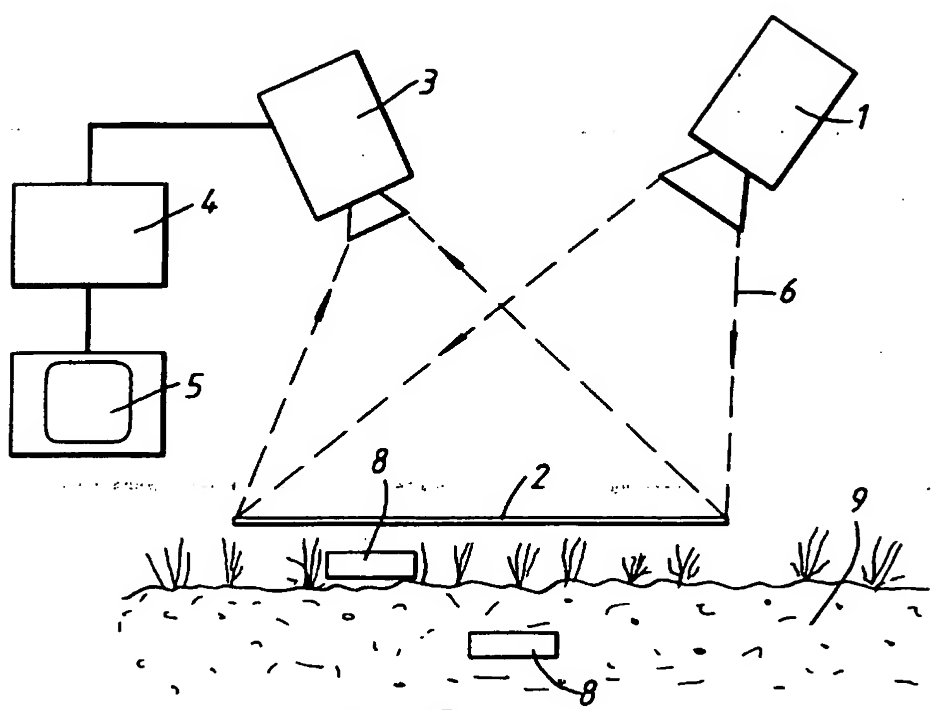

Fig.2

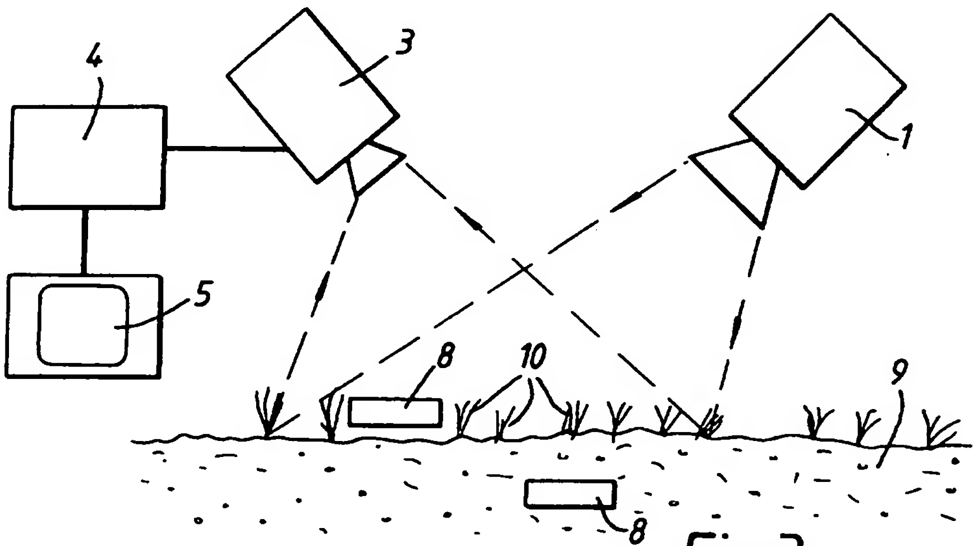

Fig.3

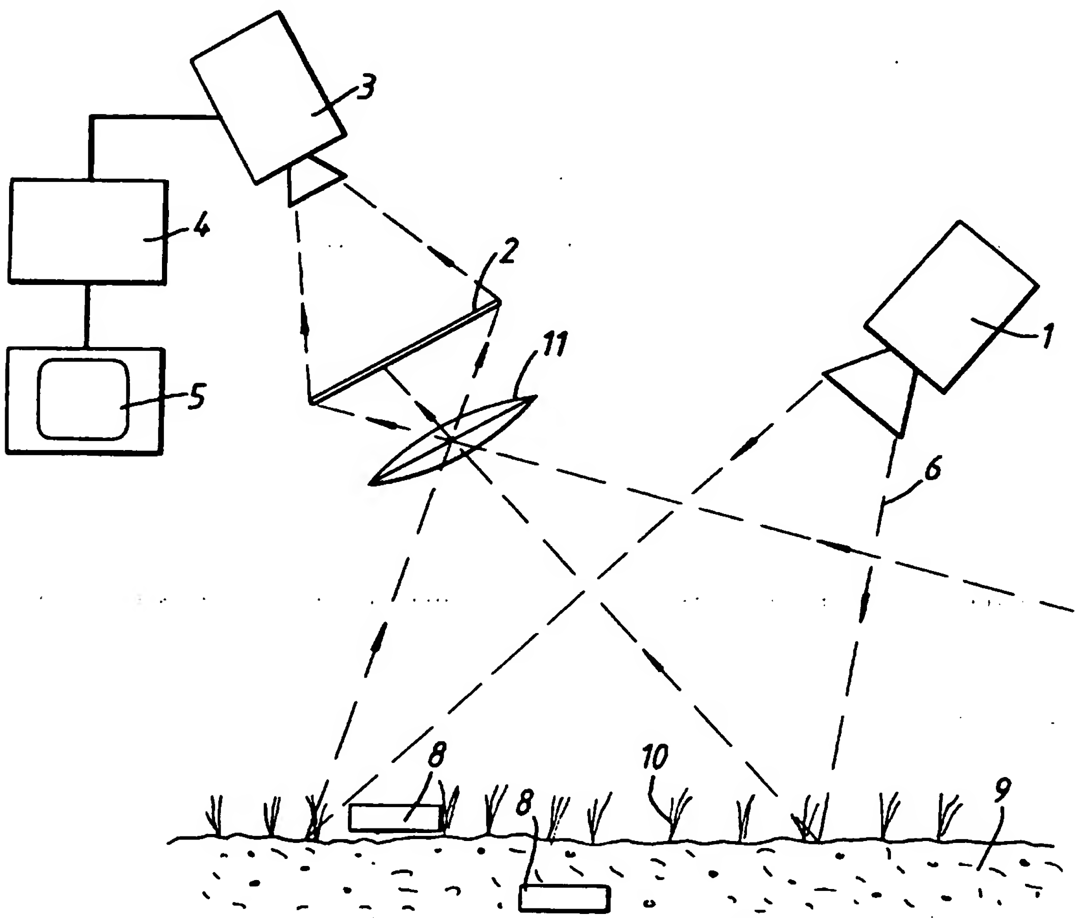

Fig.4

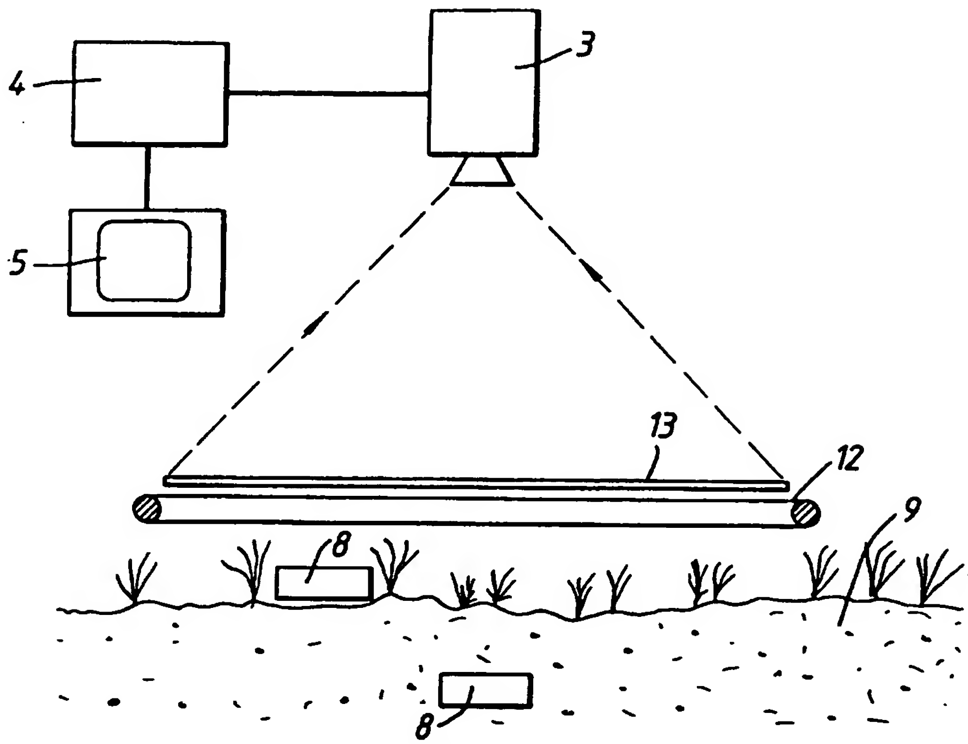

Fig.5

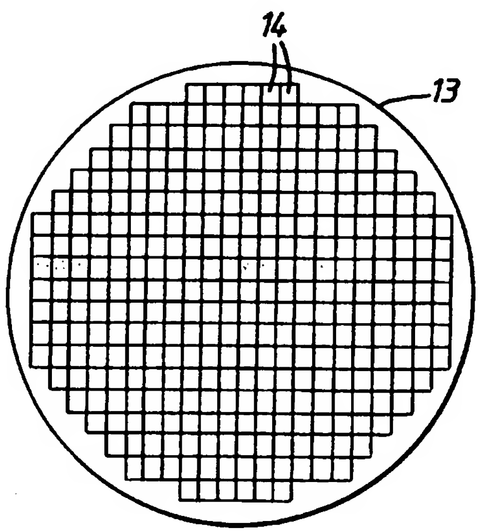

Fig.6

IMAGING METHOD AND SYSTEM

This invention relates to an imaging method and system, in particular though not exclusively, for use in locating hidden objects. Electromagnetic (EM) waves at frequencies lower than those of millimetric waves, and also low impedance magnetic waves of any frequency, have the ability to penetrate media such as soil or vegetation, and hence can be used for detecting the presence of reflective objects buried within the medium such as wires pipes and the like. The conventional way of designing such an imaging radar is to consider a plurality of antenna elements, each element corresponding to a single pixel in the subsequent radar image. Such an array, along with the consequential signal amplifiers, is large complicated and expensive.

In a first aspect this invention provides an imaging method which comprises directing EM waves at a region to be imaged in such a way as to form, on a resistive surface, a spatially varying interference pattern between EM waves reflected from an object within the region and EM waves directly incident on the surface, and observing, using a thermal imager, the thermal image formed on the surface resulting from heating by the interference pattern.

As used herein the term "EM waves" is intended to encompass waves not only having a substantial electrical component, but also waves of a more magnetic nature having little or no such component. The resistive surface may be provided by a sheet of electrically resistive material, or may be the medium being investigated, for example soil.

The invention also provides an imaging system comprising a source of EM waves, a resistive surface within which currents can be induced by the source of EM waves to generate

heat, and a thermal imager for imaging the heated surface.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which;

Figure 1 shows schematically a system according to one embodiment of the invention for use in imaging, for example, baggage at an airport;

Figure 2 shows a system according to another embodiment of the invention for use, for example, in detecting objects buried underground;

Figure 3 shows an alternative embodiment to that of Figure 2;

Figure 4 shows a yet further alternative embodiment to that of Figure 2; and

Figure 5 shows a still further embodiment of the invention incorporating means for generating a magnetic field; and

Figure 6 is a plan view of the resistive surface for use with the embodiment of Figure 5.

Referring to Figure 1 a source of EM waves 1 is arranged to illuminate a screen 2 formed from a thin resistive material. The EM waves may vary widely in frequency but are typically between 1 and 2GHz. The source 1 may be pulsed, repetitive or a single shot device. The screen 2 may be formed, e.g., from a plastics material having a thin metallic coating. A thermal

imager 3 is located on the other side of the resistive sheet 2. The thermal imager 3 is connected to image processing equipment 4 and a display 5. The arrangement shown is suitable for use within a baggage inspection system where an item of luggage 7 within which a metallic object 8 is located passes through a beam of EM waves 6. A pattern is generated at the screen which is due to variations in density of the waves caused by scattering from the metallic object 8, and directly hitting the screen. Because of the resistance of the screen 2 the waves induce electrical conduction currents which are converted into heat, the heat pattern across the surface corresponding to the image density variations of the waves. By using a relatively short burst of high intensity waves, the heat pattern is formed in a time which is short compared to the thermal flows within the sheet 2. The heat pattern is captured by the thermal imager 3 before it diffuses away by the thermal flows. It is noted that in this respect the method differs from known methods in which thermal anomalies imaged occur as a result of heat flows, requiring heating of an object. In this invention thermal anomalies do not arise from the thermal properties of the object being imaged. The processor 4, knowing the features of the illumination such as wavelength and polarisation, calculates the boundary conditions giving rise to the pattern and an image of the object 8 is then displayed on the screen 5.

The embodiment shown in Figure 2 is intended for locating objects 8 buried below the ground or located on the surface, but hidden by vegetation. The arrangement is generally similar to that shown in Figure 1 and the same parts are identified by the same reference numerals. The resistive screen 2, which is partially transmissive, is located adjacent the ground with the thermal imager 3 and EM source 1 located on the same side above the screen. The arrangement is such that waves 6 pass through the screen 2 and into the soil 9 and are reflected from objects 8 onto the screen 2 to generate an interference pattern in the same way as that described with reference

to Figure 1.

Figure 3 shows a variation in which no screen in used, instead the resistance of the soil, or other like medium 9, is used to create a surface heat pattern which is imaged and processed as described previously. The heat pattern is present within even a textured surface such as would be observed from vegetation 10. This texture may be substantially removed by image subtraction techniques. By taking one image frame just before the burst of electromagnetic energy, then a second frame just after the burst, subtraction of the two will leave only those areas which have changed temperature as a result of the electromagnetic waves.

The embodiment shown in Figure 4 is generally similar to that shown in Figure 2 except that the screen 2 is of smaller area and is located further away from the ground 9. A lens 11 is arranged to focus waves reflected from the ground 9.

In the embodiment shown in Figure 5 a coil 12 located beneath a resistive sheet 13 is arranged to generate magnetic waves, typically of the order of 1KHz, which can be reflected from metallic objects 8 onto a resistive surface or screen 13. Because the waves are more magnetic in nature the screen 13 is constructed of a plurality of discrete or isolated resistive patches 14, as shown in Figure 6. Magnetic eddy currents are induced around the periphery of each patch and are then converted to heat, and in this way each patch 14 can be considered as a pixel element. The coil 12 could be located ahead of a vehicle so that large areas of ground could be quickly surveyed.

CLAIMS

1. An imaging method which comprises directing EM waves at a region to be imaged in such a way as to form on a resistive surface a spatially varying interference pattern between EM waves reflected from an object within the region and EM waves directly incident on the surface, and observing, using a thermal imager, the thermal image formed on the surface resulting from heating by the interference pattern.

2. An imaging method according to claim 1 in which the method comprises locating a resistive screen to one side of a region to be imaged, directing the electromagnetic waves through the region onto one side of the screen and observing the resultant thermal image from the other side of the screen.

3. An imaging method according to claim 1 in which the method comprises locating a partially transmissive resistive screen to one side of a region to be imaged, directing the EM waves through from one side of the screen onto the region, and observing the thermal image from the one side of the screen.

4. A method according to claim 1 which comprises directing the EM waves at soil, or a like resistive medium, for imaging objects on or within the soil.

5. A method according to claim 4 which comprises the preliminary step of taking a thermal image prior to directing the EM waves at the soil and subtracting the final image from the preliminary image to remove the effects of vegetation located upon the soil.

6. A method according to claim 1 comprising locating the imager relative to the source of EM waves such that the waves reflect from a region to be imaged and onto a resistive screen designed to absorb substantially all of the incident EM energy.

7. A method according to claim 6 including the step of locating a lens to one side of the screen so as to focus the incident EM energy.

8. A method according to claim 1 in which the EM waves are substantially magnetic waves and in which the resistive surface comprises a screen subdivided into a plurality of discrete regions, heating of the regions then being induced by eddy currents within each region.

9. An imaging system comprising a source of EM waves, a resistive surface within which currents can be induced by the source of EM waves to generate heat, and a thermal imager for imaging the heated surface.

10. An imaging system according to claim 9 in which the resistive surface comprises a screen, the EM source and thermal imager being located on opposite sides of the screen.

11. An imaging system according to claim 9 in which the resistive surface comprises a screen, the EM source and the thermal imager both being located on the same side of the screen.

12. An imaging system according to claim 9 or 10 in which a lens is located in front of the

resistive surface for focusing rays onto the surface.

13. An imaging system according to claim 9 in which the EM source is arranged to generate magnetic waves and in which the resistive surface is sub divided into a plurality of discrete regions.

14. An imaging method substantially as described with reference to any one of the drawings.

15. An imaging system substantially as described with reference to any one of the drawings.